chapter three

Transportation Safety

In 1996, 44,505 people in the United States lost their lives in crashes and incidents involving transportation vehicles, vessels, aircraft, and pipelines. Transportation fatalities account for slightly under half of all U.S. accidental deaths.

Despite the enormous toll, much progress has been made in improving transportation safety over the last three decades. Indeed, the number of fatalities for most modes in 1996 was much lower than in 1970, even though travel has doubled (see table 3-1). Yet, there is little reason for complacency, and, as is discussed subsequently in the modal profiles section of this chapter, safety indicators for some modes have shown little improvement in the last several years.

Fatalities and injuries occur in all modes, but crashes involving motor vehicles[1] account for almost 95 percent of all transportation fatalities and most injuries. Motor vehicle and firearm fatalities were the two leading causes of injury deaths in the United States in 1996, accounting for 29 and 24 percent of all injury deaths,[2] respectively (USDHHS 1997). Societal economic losses from motor vehicle crashes are huge, estimated by the National Highway Traffic Safety Administration (NHTSA) to exceed $150 billion annually (Blincoe 1996).

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[1] Includes crashes involving pedestrians and pedalcyclists struck by motor vehicles, occupants of cars, trucks, and buses, and motorcycle riders.
[2] Injury deaths (i.e., those deaths that are not due to a disease or medical procedure) include unintentional injury, suicide, homocide, legal intervention, and injury from war operations.

Table 3-1.
Fatalities, Injuries, and Accidents/Incidents by Transportation Mode

Year	Air carrier[1]	Commuter air[2]	On-demand air taxi[3]	General aviation[4]	Motor vehicles[5]	Rail[6]	Transit[7]	Water-borne[8]	Recre-ational boating	Gas and hazardous liquid pipeline
Fatalities: 1960–96										
1960	499	N	N	N	36,399	924	N	N	819	N
1965	261	N	N	N	47,089	923	N	N	1,360	N
1970	146	N	N	1,310	52,627	785	N	178	1,418	[R]30
1975	[R]124	28	69	1,252	44,525	575	N	243	1,466	[R]15
1980	1	37	105	1,239	51,091	584	N	206	1,360	19
1985	526	37	76	[R]956	43,825	454	N	131	1,116	[R]33
1990	39	7	50	[R]765	44,599	599	339	85	865	9
1991	50	77	[R]70	[R]794	41,508	586	300	30	924	14
1992	33	21	[R]68	[R]857	39,250	591	273	[R]96	816	15
1993	1	24	42	[R]736	40,150	653	281	[R]110	800	17
1994	239	25	63	[R]730	40,716	611	320	[R]69	784	22
1995	168	9	52	[R]734	41,817	567	274	46	829	21
1996	380	14	63	631	41,907	551	264	50	709	20
Injuries: 1985–96										
1985	30	16	43	517	N	31,617	N	172	2,757	126
1990	39	11	36	391	3,231,000	22,736	54,556	175	3,822	76
1991	26	30	27	420	3,097,000	21,374	52,125	110	3,967	98
1992	13	5	19	418	3,070,000	19,408	55,089	[R]167	3,683	118
1993	16	2	24	386	[R]3,149,000	17,284	52,668	[R]160	3,559	112
1994	35	6	32	452	[R]3,265,000	14,850	58,193	[R]179	4,084	[R]1,971
1995	25	25	14	395	[R]3,465,000	12,546	57,196	145	4,141	64
1996	77	2	20	359	3,511,000	10,948	55,288	129	4,442	85
Accidents: 1985–96										
1985	[R]21	21	154	[R]2,739	N	3,275	N	3,439	6,237	[R]517
1990	24	16	106	[R]2,215	6,471,000	2,879	58,077	3,613	6,411	[R]378
1991	26	22	87	[R]2,175	6,117,000	2,658	46,418	2,222	6,573	[R]449
1992	18	23	76	[R]2,073	6,000,000	2,359	36,380	[R]3,244	6,048	[R]389
1993	23	16	69	[R]2,038	[R]6,106,000	2,611	30,559	[R]3,425	6,335	447
1994	[R]23	10	[R]85	[R]1,995	[R]6,496,000	2,504	29,972	[R]3,972	6,906	[R]465
1995	[R]36	[R]11	[R]75	[R]2,055	[R]6,699,000	2,459	25,683	[R]4,196	8,019	349
1996	38	12	89	1,905	6,842,000	2,443	21,412	3,799	8,026	380

[1] Large carriers operating under 14 CFR 121, all scheduled and nonscheduled service.
[2] All scheduled service operating under 14 CFR 135.
[3] Nonscheduled service operating under 14 CFR 135.
[4] All operations other than those operating under 14 CFR 121 and 14 CFR 135.
[5] Includes passenger cars, light trucks, heavy trucks, buses, motorcycles, other or unknown vehicles, and nonoccupants. Motor vehicle fatalities at grade crossings are counted here.
[6] Includes fatalities resulting from train accidents, train incidents, and nontrain incidents. Injury figures also include occupational illness. Railroad accidents include train accidents only. Motor vehicle fatalities at grade crossings are counted in the motor vehicle column.
[7] Includes motor bus, commuter rail, heavy rail, light rail, demand response, van pool, and automated guideway. Some transit fatalities are also counted in other modes. Reporting criteria and source of data changed between 1989 and 1990. Starting in 1990, fatality figures include those occurring throughout the transit station, including nonpatrons. Fatalities and injuries include those resulting from incidents of all types. Accidents/Incidents include only collisions and derailments/vehicles going off the road.
[8] Vessel casualties only.
KEY: N = data are nonexistent or not cited because of changes in reporting procedures; R = revised.
SOURCE: Various sources, as compiled and reported in U.S. Department of Transportation, Bureau of Transportation Statistics, National Transportation Statistics 1998, available at http://www.bts.gov/ntda/nts.

Our increasingly mobile society exposes all age groups to the risks of crashes, as passengers, as drivers, and as pedestrians. Motor vehicle crashes are the leading cause of death for people between 6 and 27 years of age (USDOT NHTSA 1998).

To illustrate the loss that motor vehicle crashes impose on society, a metric called years of potential life lost (YPLL) before age 75 can be applied.[3] Table 3-2 shows that over the last 15 years the country has seen a drop of 32 percent in YPLL from motor vehicle crashes, almost twice the decrease in YPLL for all causes of death. The YPLL estimates, however, fail to account for people over the age of 75, a fast growing segment of the population.

People are living longer and driving for more years than ever before. There were 16.5 million licensed drivers in 1995 who were age 70 or older, about a 47 percent increase from 1985 (USDOT NHTSA 1997). Older drivers and their special needs will continue to be a factor in traffic and vehicle planning decisions as the baby boom cohort ages. Injuries to elderly passengers and elderly pedestrians involved in transportation crashes and incidents are more likely to prove fatal or to have lasting health impacts than the same injuries would for younger adults.

People are also exposed to transportation risks at work. Transportation-related incidents in transportation occupations and industries account for some of the highest rates of occupational fatalities and injuries in the economy. In 1996, 6,112 workers died from occupational injuries: about 36 percent died in motor vehicle or aircraft crashes, or in accidents involving railroads or water vessels. Among those killed were 785 truck drivers, 100 airplane pilots and navigators, and 65 taxicab drivers and chauffeurs. Workers in the transportation and public utilities industries experience fatality rates (deaths per 100,000 employees) far higher than those in the economy as a whole—13.1 versus 4.8. Fatality rates, however, are higher in the mining and agri-

[3] This measure of premature mortality was developed by the National Center for Health Statistics. Since 1996, YPLL has been calculated for persons under 75 years of age; before 1996, 65 years of age was the ceiling used. Average life expectancy in the United States is over 75 years.

Table 3-2.
Years of Potential Life Lost Before Age 75 for Selected Causes of Death
(Per 100,000 population under 75 years of age)

	1980		1990		1995		Percentage change
	Years	Percent	Years	Percent	Years	Percent	1980–95
Total population (thousands)	226,546	100.0	248,718	100.0	262,890	100.0	16.0
Under 75 years of age (thousands)	216,577	95.6	235,684	94.8	248,089	94.4	
Cause of death							
All causes of death	9,814	100.0	8,793	100.0	8,128	100.0	–17.2
Motor vehicle crashes	1,011	10.3	789	9.0	688	8.5	–31.9
Other unintentional injuries	678	6.9	474	5.4	468	5.8	–31.0
Suicide	403	4.1	406	4.6	406	5.0	0.7
Homicide and legal intervention	461	4.7	466	5.3	436	5.4	–5.3
Other causes	7,262	74.0	6,658	75.7	6,131	75.4	–15.6

SOURCE: U.S. Department of Health and Human Services, National Center for Health Statistics, Centers for Disease Control, *Health, United States, 1996–97* (Hyattsville, MD: 1997), tables 1 and 32.

cultural industries, at over 20 deaths per 100,000 workers in 1996 (USDOL OSHA 1997).

Ensuring the safe passage of people, goods, and vehicles that carry them is the highest priority of the U.S. Department of Transportation (DOT) (USDOT 1997). Keeping track of safety trends is essential for monitoring progress toward achieving this goal, and good data are required for this purpose.

This chapter summarizes recent safety statistics, discusses trends, and evaluates data adequacy in light of current modal issues. Particular attention is paid to the need for better measures of exposure to risk of death, injury, or property damage by users of the transportation system. The chapter also discusses causes of transportation crashes and incidents (with special attention given to the weather), and features a discussion of transportation safety and the elderly.

A PERSPECTIVE ON RECENT CRASHES

The numbers of fatalities and injuries tallied in the national statistics are so large that the human toll that lies behind these statistics is difficult to grasp. In some ways, the reality behind these figures is understood more keenly by focusing on particular crashes or accidents, each with its own set of circumstances. In many cases, investigation of particular incidents reveals a broader problem needing the attention of safety officials and organizations.

Table 3-3 lists examples of the U.S. transportation crashes and accidents that occurred from mid-summer 1996 through the end of 1997. These incidents reflect one or more of the following circumstances: a large number of fatalities relative to transportation incidents for the mode concerned; substantial property or environmental damage; extensive public attention; or a highly visible safety issue, such as school bus safety or safety concerns about pipelines in densely populated areas. The incidents in the table are not intended to be representative of incidents in these modes and do not reflect the frequency of accidents in these modes.

Although 19 of 20 transportation fatalities take place on highways, most fatal highway crashes involve one or two deaths and seldom attract national or international attention. An exception (not listed in table 3-3 because it occurred in France) was the death of Princess Diana, her friend, Dodi Al Fayed, and their driver in a high-speed crash in August 1997. Although still under investigation, the crash focused worldwide attention on the tragic impacts of motor vehicle crashes and increased awareness of safety issues. Tests showed the driver to be legally intoxicated by French standards. Also, the only survivor of the crash was wearing a safety belt.

The relatively small share of motor vehicle crashes that involve multiple fatalities also can focus public attention on safety issues. One example occurred on July 29, 1997, in Michigan. Eleven people, including nine children, died when a pickup truck ran a stop sign and was rammed by a dump truck; the children were riding in the rear of the pickup truck. Another example that received national attention occurred in June 1997. Four pedestrians were killed and three injured when they were struck by an urban transit bus at a "park and ride" facility in Missouri. The National Transportation Safety Board (NTSB) found that the driver, a trainee, misapplied the accelerator of the bus. A contributing factor was inadequate separation between the roadway of the transit facility and its pedestrian platform (NTSB 1998a).

These high profile crashes are dramatic illustrations of a more general fact about motor vehicle safety. Most motor vehicle crashes are in some sense preventable, and human factors contribute to a high proportion of crashes. Choices made by drivers and occupants affect their expo-

Table 3-3.
Selected Transportation Crashes and Incidents: September 1996–December 1997

Date	Mode	Location	Incident	Consequence
9/4/96	Highway	Washington, DC	Bus with elderly tourists collided with sport utility vehicle on Interstate highway	1 death, 32 injuries
9/5/96	Water	Cape Ann, MA	Collision between fishing vessel and tank barge	3 deaths, tank barge capsized
9/6/96	Air	Newburgh, NY	Cargo/courier jet in-flight fire	Plane destroyed, minor injuries
9/27/96	Water	Portland, ME	Liberian tank vessel rammed the Million Dollar Bridge, with oil spill	Substantial damage to ship and bridge, 170,000 gallons of oil spilled into waterway
11/19/96	Air	Quincy, IL	Commuter plane collided on runway with private plane	14 deaths, both planes destroyed
11/21/96	Pipeline	San Juan, PR	Leak and explosion of gas line in residential and shopping district	33 deaths, 69 injuries, damage to buildings and cars in adjacent area
11/23/96	Rail	Secaucus, NJ	Derailment of an Amtrak train, which sideswiped another Amtrak train on adjacent track	43 injuries, more than $3.6 million in damages, 12 cars derailed
12/7/96	Water	Marina del Rey, CA	Fire on pleasure craft near dock	62 passengers jumped into water
12/14/96	Water	New Orleans, LA	Ramming of wharf and adjacent mall, hotel, and parking garage by Liberian bulk carrier	4 serious injuries, 58 minor injuries, $20 million in damages
12/22/96	Air	Narrows, VA	Courier jet crashed in post-maintenance flight test	6 deaths, plane destroyed
1/9/97	Air	Monroe, MI	Commuter plane crashed on landing approach and burned	29 deaths, plane destroyed
1/12/97	Rail	Kelso, CA	Derailment of freight train	$4.4 million in damages, 3 locomotives and 68 cars derailed
1/13/97	Highway (Transit)	Cambridge, MA	Transit bus plunged through ice into Charles River	1 death
2/12/97	Highway	Slinger, WI	Double tractor-trailer crossed median and back with multiple collisions	8 deaths, 4 injuries
4/10/97	Highway	Monticello, MN	School bus hit by gravel truck	4 deaths
6/11/97	Transit	Normandy, MI	Transit bus struck 7 pedestrians at park and ride facility	4 pedestrians deaths, 3 injuries

(continued on following page)

Table 3-3.
Selected Transportation Crashes and Incidents: September 1996–December 1997 *(continued)*

Date	Mode	Location	Incident	Consequence
7/2/97	Rail	Rossville, KS	Collision and fire on 2 freight trains carrying hazardous materials	1 death, 1 injury, evacuation of 1,000 nearby residents
7/29/97	Highway	Concord, MI	Pickup truck ran a stop sign; hit by dump truck at intersection	11 deaths, including 9 children riding in the back of the pickup truck
7/29/97	Highway	Petersburg, VA	Charter bus carrying children plunged into Virginia River	1 death, 10 injuries
7/31/97	Air	Newark, NJ	Courier jet bounced on landing and burned	Plane destroyed
8/6/97	Air	Guam	Foreign air carrier jet crashed while trying to land	226 deaths, plane destroyed
8/7/97	Air	Miami, FL	Cargo jet crashes near Miami airport	5 deaths, plane destroyed
8/9/97	Water	Gloucester, MA	Fire on, and subsequent sinking of, whale-watching boat	143 passengers rescued by Coast Guard
8/18/97	Highway	Baltimore, MD	Gasoline tanker truck overturned on beltway, with explosion	1 death, 2,800 gallons of gasoline exploded, Interstate highway closed for several hours
11/17/97	Highway	Mendota, CA	Van carrying 12 people collided with semi-trailer while trying to pass in fog	11 deaths, van destroyed
12/11/97	Highway	Sacramento, CA	Fog on Interstate highway caused multiple crashes and fires involving 36 vehicles	5 deaths, 26 injuries
12/14/97	Multi-modal	Littleton, CO	Medical helicopter snagged in power lines after picking up auto crash victims	4 deaths in helicopter, 1 death in car crash, 15,000 lose electrical power
12/28/97	Air	Pacific Ocean	Jet airliner hits severe turbulence at 31,000 feet	1 death, 102 injuries

NOTE: A September starting date was selected to provide continuity with a similar table in *Transportation Statistics Annual Report 1997.*

sure to risk. For example, the risks of highway travel are quite different for a passenger wearing a safety belt in a car driven by a careful driver at a safe speed than the risks of travel for an unbelted passenger in a car driven at high speed by an aggressive driver.

Although commercial aviation accounts for only a small share of transportation fatalities, the crash of a large passenger jet usually prompts a great deal of public and media attention. The crashes of ValuJet 592 on May 11, 1996, and TWA 800 on July 17, 1996, with 110 and 230 fatalities, respectively, were in the daily news for many weeks. Another major air disaster, this one involving a foreign carrier, took place in Guam (a self-governing U.S. territory) in August 1997, when 226 people died. Two other crashes involving foreign carriers focused attention on the safety of air operations in other countries. In November 1996, airplanes from Saudi Arabia and Kazakstan collided, killing at least 349 people in history's deadliest midair crash. In December 1997, an Indonesian crash in dense haze arising from forest fires claimed 97 lives. These and other crashes outside the United States have contributed to a growing concern for the safety of U.S. citizens traveling abroad. According to the American Travel Survey, Americans took nearly 27 million roundtrips by air to destinations outside the United States in 1995 (USDOT BTS 1997).

Despite the great attention focused on commercial airline crashes, general aviation crashes involving private planes operated by individuals and businesses claim far more lives each year on average. Like motor vehicle crashes, general aviation crashes seldom receive much national media attention. An exception in 1997 was the crash that claimed the life of entertainer John Denver, who was piloting his own experimental aircraft. As is discussed in the modal profile section, good exposure measures for general aviation are lacking.

Exposure to transportation risk is not limited to people on the move. Bystanders, people on nearby property, or even nearby communities can be exposed to risks—albeit remote—as is suggested by several of the incidents in table 3-3. Since 1990, there have been, on average, nearly 300 accidents each year related to the transportation of hazardous materials (excluding pipelines).

Hazardous materials incidents, such as the overturning of a gasoline tanker truck on the Baltimore, Maryland, beltway in August 1997, and the collision of freight trains carrying hazardous materials near Rossville, Kansas, in July 1997, can require closing of highways and evacuation of nearby residents as a precaution.

People in a commercial district of San Juan, Puerto Rico, were the victims of a deadly pipeline accident that occurred in November 1996, and resulted in 33 deaths and 80 injuries. The NTSB investigation of the disaster found that leaking propane from a cracked pipe, damaged several years earlier from excavation, fueled the explosion (NTSB 1997). Excavation damage is a perennial pipeline safety problem.

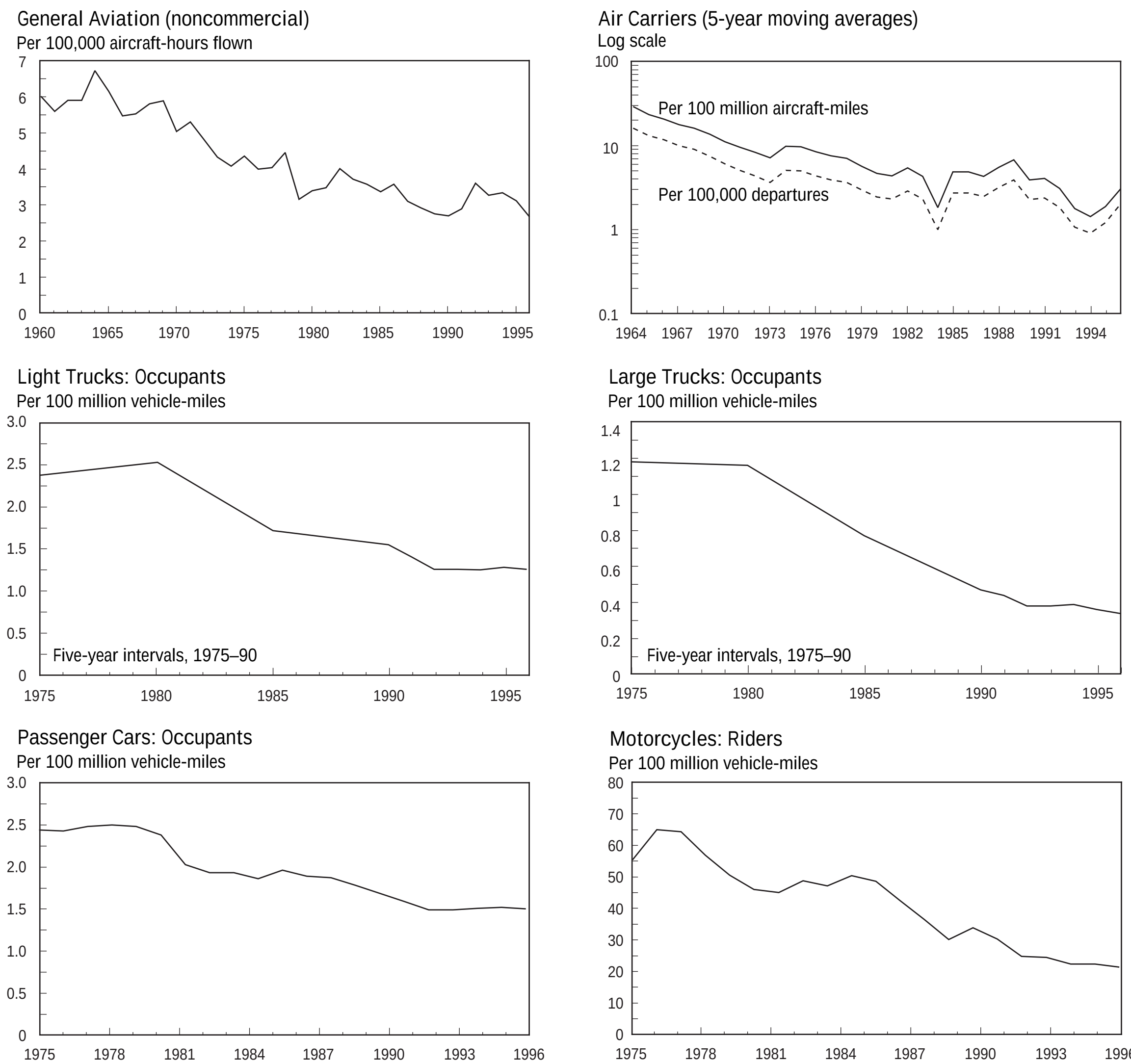
In another incident, a Mississippi River bulk carrier rammed a wharf adjoining a waterfront mall in New Orleans in December 1996, causing substantial property damage and four serious injuries. The vessel temporarily lost propulsion power, a failure NTSB ascribed to inadequate management and oversight of maintenance of the vessel's powerplant. This accident highlights the risks of siting commercial development in locations vulnerable to vessel mishaps. According to NTSB, inadequate efforts had been made to assess, manage, or mitigate these risks (NTSB 1998b).

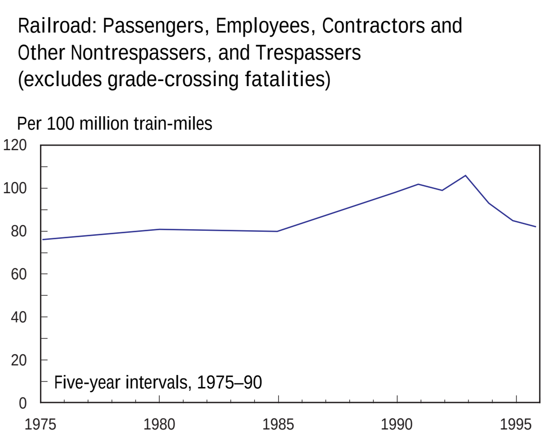
MODAL PROFILES

Figure 3-1 shows fatality rates by specified unit of exposure for selected transportation modes. (Rates are calculated using occupant fatalities where data permit.) The long-term improvement in occupant safety is evident here as in table 3-1 (which showed change in absolute number of fatalities). As is discussed subsequently, good exposure measures by which to analyze some modes, such as recreational boating, are not available. The number of boating fatalities has trended downward, however, while activity levels are likely to have increased. Hence, improvement in boating fatality rates is also likely.

Table 3-4 shows the distribution of transportation fatalities in 1996. Over 77 percent of the fatalities were occupants of cars, light trucks (including sport utility vehicles), or motorcyclists. Another 14 percent were pedestrians or bicyclists struck by motor vehicles. Recreational boating and general aviation (including private business planes and private-use planes) together

Figure 3-1.
Fatality Rates for Selected Modes





SOURCES: General aviation—For 1960–74, data include air taxi. Data from U.S. Department of Transportation, Federal Aviation Administration, *FAA Statistical Handbook* (Washington, DC: 1960–74). For 1975– 96: National Transportation Safety Board, *Annual Review of Aircraft Accident Data, General Aviation* (Washington, DC: Annual volumes). For all other modes: U.S. Department of Transportation, Bureau of Transportation Statistics, National Transportation Statistics 1998, available at http://www.bts.gov/ntda/nts.

Table 3-4.
Distribution of Transportation Fatalities: 1996

Category[1]	1996	Percent
Total	44,505	100.0
Passenger car occupants	22,416	50.4
Light-truck occupants	9,901	22.2
Pedestrians struck by motor vehicles	5,412	12.2
Motorcyclists	2,160	4.9
Pedalcyclists struck by motor vehicle	761	1.7
Recreational boating	709	1.6
General aviation	631	1.4
Large-truck occupants	621	1.4
Railroad[2] (excluding grade crossings)	551	1.2
Other and unknown motor vehicle occupants	460	1.0
Air carriers	380	0.9
Other nonoccupants struck by motor vehicles[3]	153	0.3
Heavy rail transit (subway)	74	0.2
Grade crossings, not involving motor vehicles[4]	73	0.2
Air taxi	63	0.1
Waterborne transportation	50	0.1
Bus occupants (school, intercity, and transit)	21	< 0.1
Transit buses, fatalities not related to accidents[5]	19	< 0.1
Commuter air	14	< 0.1
Gas distribution pipelines	14	< 0.1
Demand response transit fatalities not related to accidents[5]	8	< 0.1
Light rail transit	6	< 0.1
Hazardous liquid pipelines	5	< 0.1
Undetermined motor vehicle occupants	2	< 0.1
Gas transmission pipelines	1	< 0.1
Other counts, redundant with above[6]		
Grade crossings, with motor vehicles	415	
Transit buses, accident-related fatalities	82	
Commuter rail	72	
Passengers on railroad trains	12	
Demand response, accident-related fatalities	3	

[1] Unless otherwise specified, includes fatalities outside the vehicle.
[2] Includes fatalities outside trains.
[3] Includes all nonoccupant fatalities, except pedalcyclists and pedestrians.
[4] Grade-crossing fatalities involving motor vehicles are included in counts for motor vehicles.
[5] Fatalities not related to accidents for transit buses and demand response transit are not included under highway submodes.
[6] Fatalities at grade crossings with motor vehicles are included under relevant motor vehicle modes. Commuter rail fatalities are counted under railroad. For transit bus and demand response transit accidents, occupant fatalities are counted under "bus" and nonoccupant fatalities are counted under "pedestrians," "pedalcyclists," or other motor vehicle categories.

SOURCES: Various sources, as compiled and reported in U.S. Department of Transportation, Bureau of Transportation Statistics, National Transportation Statistics 1998, available at http://www.bts.gov/ntda/nts.

accounted for 3 percent of the fatalities—more than all commercial passenger modes and freight trains combined. Occupants of large trucks accounted for 1.4 percent of all transportation fatalities, although large trucks were involved in crashes that resulted in 11.5 percent of the fatalities in the table.

The following modal profiles focus on selected safety concerns that have implications for the collection and analysis of data.

Motor Vehicles

The nation's highways are much safer now than 30 years ago, even though vehicle-miles have doubled. Both the absolute number of motor vehicle fatalities and the rates have declined. If the fatality rates in the late 1960s—more than 5 fatalities per 100 million vehicle-miles—had persisted, more than twice as many people would have died on the road in 1996 than actually were killed. (This estimate factors in the decrease in occupancy rates of motor vehicles since the late 1960s.)

The improvements, however, leveled off in the 1990s. In 1992, there were 39,250 motor vehicle fatalities, the fewest deaths since 1962. Subsequently, the numbers of deaths have started to rise. Because travel has increased, the fatality rate has stayed flat at 1.7 fatalities per 100 million vehicle-miles.

Numerous factors interact to affect highway safety: roadside safety features, demographics, vehicle size, onboard equipment, use of occupant protection devices, driver and pedestrian distractions and fatigue, alcohol and drug use, and vehicle speed, to cite just a few. The beneficial effects of programs to discourage alcohol abuse and encourage use of occupant protection devices, technological advances such as antilock braking systems and traction control, and advances in trauma intervention are apparent. Yet, only about two-thirds of Americans use safety belts, despite evidence that their use saves lives and reduces injury severity in crashes. (See box 3-1 for a discussion of alcohol and drug involvement in crashes.) New approaches, in addition to maintaining those already working well, will also be essential if there is to be improvement in fatality, injury, and crash rates.

► Safety Effects of Speed Limit Changes

In December 1995, Congress repealed the last federal provisions for a 55 miles per hour (mph) speed limit. The 55 mph limit, put in place nationwide in 1974, was adjusted in 1987 to allow states to raise rural Interstate limits to 65 mph. The 1995 repeal granted states sole authority to set speed limits on all roads within state boundaries. As of August 1997, only Connecticut, the District of Columbia, Hawaii, and New Jersey had elected not to raise speed limits on at least some part of their Interstate highways. The upper speed limit, types of roads and vehicles eligible, and other circumstances vary greatly among states. Montana, for example, has no specified upper limit for daytime speed on rural Interstates. Ten states have set lower speed limits for trucks than for passenger vehicles on their rural Interstate highway segments.

Many analytical efforts have tried to assess the crash impacts of speed limit increases in a particular state for a certain period; however, the conclusions of these studies differ. A 1997 study found an association between higher speed limits and occupant fatalities (Farmer et al 1997). The study compared data for the 12 states that increased their speed limits to 70 mph or higher on Interstate highways with data from 18 states that either did not raise limits, or raised limits on less than 10 percent of urban mileage. The states with 70 mph and higher limits experienced a 12 percent or higher increase in occupant fatalities. A smaller increase was found on other types of roads.

A report to Congress, released in 1998, detailed the findings of a jointly sponsored

Box 3-1.
Alcohol and Drug Involvement in Transportation Crashes and Incidents

Alcohol and drug involvement are factors in transportation crashes and incidents, and account for a high number of fatalities each year. Reporting agencies use a variety of definitions and procedures to determine alcohol and drug involvement, making comparable cross-modal tallies difficult. Testing drivers or operators involved in crashes for alcohol is common. For motor vehicle drivers, most states use a blood alcohol concentration of 0.10 grams per deciliter as the legal definition of intoxication, although 13 states have set the limit at 0.08. Also, 38 states have a lower limit for young drivers. The police use field sobriety tests and breathalyzers routinely at the site of a motor vehicle crash. In the case of transit employees, a saliva testing device is used to test for alcohol. Testing for drug involvement in transportation crashes is more difficult than alcohol testing, since urine samples must generally be obtained.[1] Even then, only some drugs can be verified conclusively.

In 1996, alcohol was a factor in crashes involving motor vehicles that claimed 17,126 lives or 41 percent of all highway fatalities that year. Alcohol involvement tallies include drivers and nonmotorists, mostly pedestrians, in fatal crashes. In 1982, at the beginning of a renewed, national effort to eliminate alcohol as a crash contributor, 25,165 fatalities, constituting 57 percent of all highway fatalities, occurred in crashes involving alcohol.

The proportion of drivers in fatal crashes varies widely by vehicle type. For instance, drivers of large trucks involved in fatal crashes had a 1.4 percent intoxication rate in 1996, while drivers of light trucks, passenger cars, and motorcycles involved in fatal crashes had 22, 19, and 30 percent intoxication rates, respectively. Alcohol is often coupled with excessive speed. In 1996, 42 percent of intoxicated drivers involved in fatal crashes were speeding (USDOT NHTSA 1997a, 2). There is, however, no single profile of an alcohol-impaired driver.

Alcohol usage is a factor in pedestrian safety as well. In 1996, of the pedestrians killed in traffic accidents who were 14 years of age or older, 36 percent were intoxicated (USDOT NHTSA 1997b, 38).

The National Transportation Safety Board investigates aviation accidents where drugs or alcohol are suspected. In 1995, 22 fatalities occurred in general aviation accidents where the agency determined that alcohol or unapproved drugs were involved. No data were compiled for commercial air carriers. U.S. Coast Guard (USCG) investigations showed that 29 alcohol-related deaths and 6 drug-related deaths occurred for waterborne commerce in 1995. Of the 846 recreational boating fatalities in 1995, USCG records show 149 fatalities associated with alcohol use, and 17 with drug use (USDOT BTS 1997).

REFERENCES

U.S. Department of Transportation (USDOT), Bureau of Transportation Statistics (BTS). 1997. *Transportation Statistics Annual Report 1997*. Washington, DC.

U.S. Department of Transportation (USDOT), National Highway Traffic Safety Administration (NHTSA). 1997a. *Speeding: Traffic Safety Facts 1996*. Washington, DC.

_____. 1997b. *Traffic Safety Facts 1996*, DOT HS 808 649. Washington, DC. December.

[1] The National Highway Traffic Safety Administration encourages police to do more urine collection when there is suspicion of drug involvement, particularly when alcohol has been ruled out by field sobriety or breathalyzer tests. Some field tests exist for drugs, but their results are not considered to be conclusive.

NHTSA/Federal Highway Administration (FHWA) analysis of Interstate highway fatalities and economic costs associated with repeal of the national 55 mph limit (USDOT NHTSA FHWA 1998). The study is based on data from the first year of fatal crash experience, 1996, which for most states is only a partial year with the higher limits. It is estimated that fatalities on Interstates were about 9 percent higher in 32 states that increased speed limits than would have been expected given historical trends. The study noted, however, that it was not known how various traffic safety factors may have contributed to the increase; more data would be needed to conduct this analysis. No change in the expected pattern of fatalities was evident on

Interstates in states that did not raise speed limits. The study did not attempt to assess the potential benefits of the repeal—such as travel time—stating that data would need to be collected for a more protracted period. The study also included a summary of material from 10 states that conducted their own studies.

There are several factors that complicate analyses of the effects of raised speed limits. Many drivers tend to exceed posted speed limits. It is possible that for certain segments of highway on which there was a change in speed limits, actual driving speeds may show little change. Conversely, on other highway segments, actual speeds may increase by more than the increase in speed limits. The degree of enforcement of the limit, before and after the repeals, could also affect the consequences of the repeals, so could the enforcement of drunk driving laws, as alcohol use is correlated with drivers exceeding posted limits.

► Injury and Exposure Data Needs

Analysis of motor vehicle safety is impeded by the lack of meaningful risk exposure measures for specific conditions faced or induced by drivers. In addition, the number and severity of injuries is inadequately reported in national estimates.

A great deal of diverse data are needed to analyze how various conditions and countermeasures affect the number of highway crashes, and how some crashes might be prevented. Examples include: description of the attributes of crashes, such as vehicle types, persons involved, and crash circumstances; and exposure measures, such as the amount of driving by subsets of the population or by specific time period (e.g., by age or time of day). Even with the best data, it is always difficult to separate out the effects of policy and intervention measures from other factors that affect driving risk.

By dividing the number of crashes by an appropriate exposure measure, meaningful and policy-relevant rates can sometimes be developed. Practical limitations on data collection and conceptual difficulties limit the number of reliable rates.

Data with multiple attributes have been collected for years for motor vehicle-related fatalities. Samples of injury and/or property damage crashes have also been collected over a number of years, but not with the same reporting consistency. The need for better information about crashes involving injuries is clear, and several states are now participating in an effort to improve reporting of injury data (see box 3-2). This effort, called the Crash Outcome Data Evaluation System, is supported in part by NHTSA.

Where specific exposure measures are lacking, indirect methods (such as proxies) are sometimes employed. For example, if the exposure of drivers of a certain age group is sought, and data on miles driven by age group of driver are unavailable, data on the proportion of licensed drivers by age group can be used as a proxy. More sophisticated indirect methods have sometimes been used to measure the effects of interventions like safety belt laws, minimum drinking age laws, and speed limit changes, because no exposure or proxy exists. Clearly, however, more detailed benchmark exposure data would be useful for safety analysis.

The location of crashes is another fundamental data need that is inadequately addressed in current databases. Location information could facilitate development of exposure measures that account for the influence of highway design elements and the level of traffic on the number and severity of crashes.

Safety analysis would also benefit from more detailed data on fatal crashes and injury or

Box 3-2.
Motor Vehicle Crash Data

The Fatality Analysis Reporting System (FARS), begun in 1975 and maintained by the National Highway Traffic Safety Administration (NHTSA), lists every crash involving a motor vehicle on a public road[1] in which at least 1 person died within 30 days of the crash. Over 100 attributes for each crash are collected and are classified as one of four levels: crash, vehicle, person, or driver. The 23 years of FARS data make it possible to compare and interrelate attributes from these levels over time.

National estimates of injuries and nonfatal crashes are subject to many more uncertainties than fatality counts. The General Estimates System (GES), the major database on injuries, contains a sample of police accident reports (PARs) for motor vehicle crashes. In contrast to FARS, sampling errors occur because the GES includes only some PARs from state databases. Other errors arise for many reasons. For example, police at the site of a crash often have too little information and knowledge to estimate injury severity. Also, many crashes are not reported to the police. While unreported crashes generally involve only minor injuries and property damage, cumulatively they represent many injuries and sizable property damage. The General Accounting Office and others have cautioned against using PAR data for certain types of safety analyses. Because only PAR data are used, perhaps as many as half of all motor vehicle crashes not involving a fatality are not included in the GES database. Thus, estimates for accidents, injuries, and property damage are underreported.

Recently, several states, with NHTSA support, have begun developing the Crash Outcome Data Evaluation System (CODES) to provide more comprehensive and consistent information about injuries from highway crashes. For example, at least 14 states are seeking to link highway crash reporting and medical data systems. This could result in much more complete reporting about the number of injuries, their severity, and their economic costs as reflected in hospital and rehabilitation costs.

The states are also working with the federal government to develop more detailed information about truck and bus crashes. In addition to the FARS and GES, truck crash data can be found in the Motor Carrier Management Information System (MCMIS) database[2] and the Trucks Involved in Fatal Crashes file (detailed information on fatal truck crashes). The databases have different crash reporting thresholds, and for this and other reasons, the numbers of crashes reported are not always in agreement. The MCMIS statistics suffer from incomplete reporting by states. The Office of Motor Carriers receives reports on only about 61 percent of trucks involved in crashes that would be reportable under criteria recommended by the National Governors' Association.[3] The GES bus file is based on a very small sample.

REFERENCE

Venturi, C., National Highway Traffic Safety Administration, U.S. Department of Transportation. 1998. Personal communication.

[1] A public road, or trafficway, is defined as any road, street, or highway open to the public as a matter of right or custom for moving persons or property from one place to another. Fatalities that do not occur on public roads are estimated to be less than 2 percent of the annual traffic fatalities (Venturi 1998).

[2] The MCMIS is maintained by the Federal Highway Administration Office of Motor Carriers (OMC). States report crashes to OMC through the Safetynet computer reporting system. MCMIS includes data elements recommended by the National Governors' Association (NGA) and covers trucks and buses involved in crashes that meet NGA thresholds (truck with 2 or more axles and 6 more tires, or a bus with 16 or more seats, including the driver's).

[3] NGA thresholds also require at least one fatality, one injury where a person is taken to a medical facility for immediate attention, or one vehicle towed from the scene due to disabling damage.

property damage crashes involving large trucks and buses. The 1991 Intermodal Surface Transportation Efficiency Act emphasized motor carrier safety by mandating that the 48 contiguous states participate in the Safetynet program and report crashes involving large trucks and buses to the FHWA Office of Motor Carriers.[4] Several truck crash databases exist, but not all states report crashes meeting reporting thresholds (as is discussed in box 3-2).

[4] Large trucks are defined as vehicles with a gross vehicle weight of 10,000 pounds or more. Buses (e.g., school buses, transit buses, and motorcoaches) are defined as vehicles with more than 15 seats, including the driver's.

Aviation

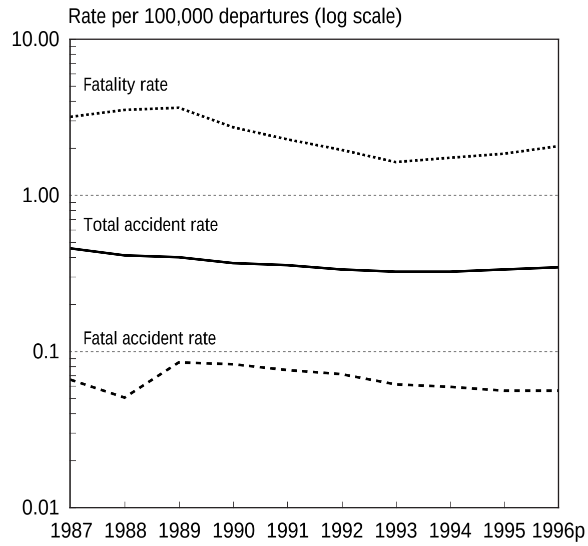
While crashes of the magnitude of TWA Flight 800 contribute to the perception on the part of some that air travel is becoming less safe than it once was, the long-term trend depicted in figure 3-1 shows that travel today on U.S. airlines is much safer than it was in the 1960s.

The most robust improvement occurred in the 1960s and 1970s. Over the last 10 years, the fatality rate, fatal crash rate, and total crash rate have remained relatively stable, as seen in figure 3-2, which expresses these rates as a moving average to reveal the trend that underlies year-to-year variations.

Concern about the long-term implications of continued growth in air travel without corresponding improvements in air safety was expressed by two recent blue-ribbon commissions on aviation safety and security. The final report by the Commission on Aviation Safety and Security was submitted to President Clinton in 1997 (USEOP 1997). The Commission recommended establishment of a national goal by government and industry of reducing the rate of fatal accidents in U.S. commercial aviation by a factor of five within a decade. The Commission further recommended that safety research be conducted to support the goal. Another group, the National Civil Aviation Review Commission, reported to Congress and the President in December 1997, urging concerted government and industry actions to improve aviation's safety and security (NCARC 1997).

The historical data show that the majority of aviation accidents occur during takeoff or landing, and a minority occur during the cruise phase of the flight. The cruise portion of the flight, however, constitutes the largest part of the total flying distance and the total flight time. Hence, of the different exposure measures—aircraft-miles, aircraft-hours flown, and number of operations (sometimes called landings and takeoffs)—the last is the best. Data on the first two exposure measures are available separately for all aircraft modes. As for the last and most preferable measure, data on the number of operations are available for major and commuter air carriers, but the number of landings for air taxi and general aviation are combined in the available data sets. Thus, data users must choose to either combine air taxi and general aviation in their analyses (which is not desirable, as the two submodes have quite different operating profiles), or rely on less useful exposure measures, that is, aircraft-miles flown or aircraft-hours operated.

Figure 3-2.
Fatality, Fatal Accident, and Total Accident Rates for Major Air Carriers: 1987–96
(10-year moving average)



KEY: p = preliminary.

NOTE: Data are for air carriers operating under 14 CFR 121, scheduled and nonscheduled service.

SOURCES:
Fatalities, accidents and fatal accidents data:
1978–81: National Transportation Safety Board, *Annual Review of Aircraft Accident Data* (Washington, DC: Annual issues).
1982–96: _____. NTSB Press Release SB 97-03, 1997.
Departures data:
Compiled by the Federal Aviation Administration, combining data from Forms 41, 298C, and 291, for Large Certificated Air Carriers, Small Certificated Air Carriers, and Express operations, respectively.

Highway-Railroad Crossing Collisions

About half of all rail-related fatalities result from collisions between trains and motor vehicles at railroad crossings. In 1996, 4,257 train-motor vehicle collisions occurred, killing 488 people and injuring another 1,610 (USDOT BTS 1998). In 1997, there were 453 grade-crossing fatalities. Figure 3-3 shows the location of all but 60 of these fatalities. More than one fatality occurred at some locations.

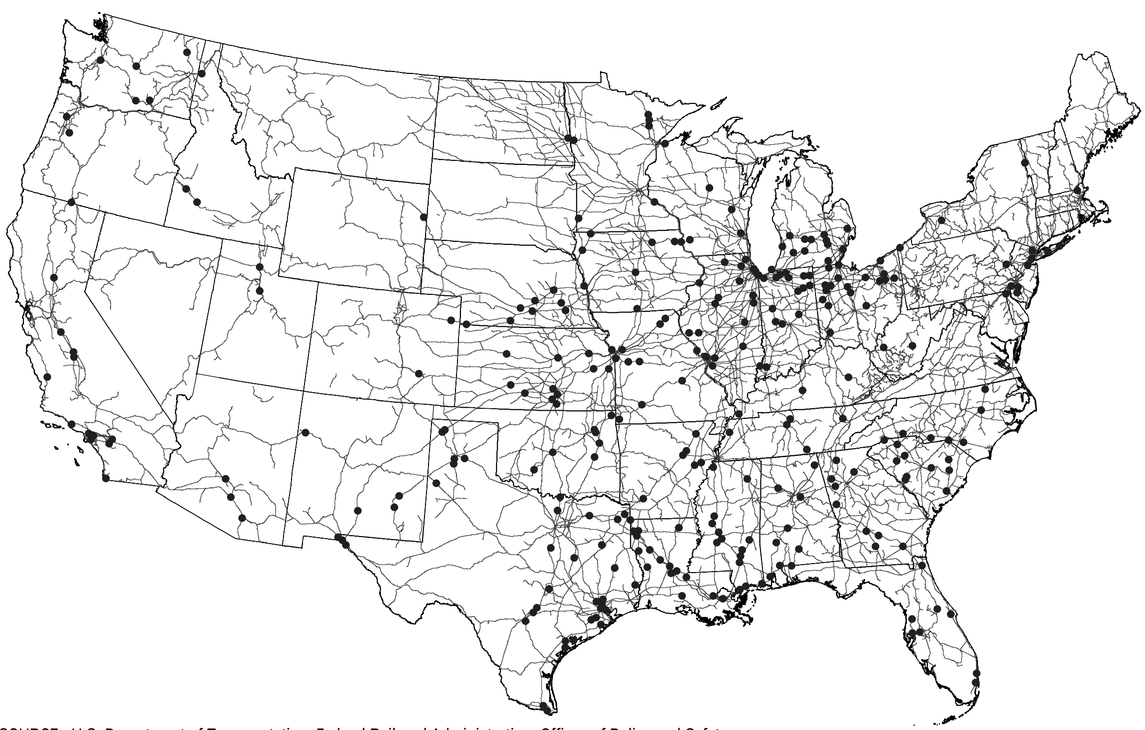
A variety of measures make many public and private grade crossings safer. In 1996, for example, 40,000 underpasses or overpasses separated trains from motor vehicles and other traffic. The vast majority of crossings, however, are at grade, and thus less safe. These include 162,000 public and 103,000 private at-grade crossings. Automatic gates have been installed on about 19 percent of public at-grade crossings, and another 18 percent have flashing lights. These and other active devices are considered more effective than passive devices such as crossbuck signs, which remain the most common form of warning. Most private crossings have no signs or signals (USDOT FRA 1997).

Public education and law enforcement also promote safety, because drivers who ignore warning indicators are a major cause of grade-crossing collisions. Under its Rail-Highway Crossing Safety Action Plan, DOT aims to reduce railroad crossing accidents and fatalities by 50 percent between 1994 and 2004.

Railroad Safety

Railroad mergers and acquisitions have led to concerns about safety. The freight rail industry has

Figure 3-3.
Grade-Crossing Fatality Locations: 1997



SOURCE: U.S. Department of Transportation, Federal Railroad Administration, Offices of Policy and Safety.

increased the tonnage it carries, while reducing the size of its workforce. In addition, more hazardous materials are being transported over rail.

Existing data make it laborious to separate fatalities and injuries in train accidents from fatalities and injuries that take place on railroad premises but do not involve moving trains. This complicates efforts to construct exposure rates for train travel. The Federal Railroad Administration includes in its fatality counts employees and other people who are not occupants on a moving train, including workers in railyards performing mechanical or electrical work, trespassers on the right-of-way, and contractors making deliveries on the premises. While including trespasser fatalities and injuries in railroad counts is similar in some respects to including pedestrian fatalities and injuries in highway counts, many more people die outside trains in railroad incidents than on them. Unless one looks very closely at the statistics, the effect is to make rail travel look less safe for passengers than it is.

Care needs to be taken to avoid double counting when analyzing railroad safety data, as commuter rail is included in both rail and transit totals. Also, data for crashes involving motor vehicles at rail-highway grade crossings may be counted in both the highway and rail totals. All double counting has been eliminated in the totals in table 3-4.

Transit

Of all modes, transit is the most eclectic. Transit vehicles operate on highways (buses), on railroad tracks or other fixed guideways (e.g., heavy and light rail, commuter rail, and cable car), and on the water (ferry boats). Transit operations often share all or part of the right-of-way with other modes. For example, buses travel primarily on city streets, although some systems operate routes using bus-only lanes. Commuter rail shares track with intercity passenger and freight rail. Surface light rail generally operates on an exclusive right-of-way, but with frequent grade crossings with motor vehicle and pedestrian traffic.

Because transit shares right-of-way with other modes, fatality, injury, and incident counts can be redundant with other modal counts. Thus, transit bus fatalities in the Safety Management Information Statistics (SAMIS) Report include not only those for transit bus occupants, but also pedestrian, pedalcyclist, and other vehicle occupant fatalities in incidents involving transit buses (USDOT FTA annual). In addition, the Fatality Analysis Reporting System (FARS) shows occupant fatalities for all buses, including transit. The SAMIS transit bus fatality count for 1996 (82) (table 3-4), might seem inconsistent with the FARS count for all buses (21). For the reasons explained above, however, there is no contradiction; the 82 transit bus fatalities from SAMIS are all counted in FARS, but spread over bus, passenger car, light truck, pedestrians, pedalcyclists, and so on. Hence, the transit bus fatalities from SAMIS *should not count* toward total fatalities for all modes. Similarly, commuter rail fatalities are included in the count for rail.

Another feature of the systemwide approach for collection of transit safety data is that all fatalities, injuries, and incidents on transit property, including those not caused by transit vehicle operations, (e.g., injuries on escalators and in parking lots) are counted. In this respect, the data problems discussed under railroad safety are similar to those in transit safety analyses.

Finally, those transit agencies receiving Urbanized Area (UA) Formula Funds are required to report transit data to the National Transit Database (NTD). This includes almost all government-owned transit agencies, as well as the vast majority of services provided under contract by private companies. Transit agencies not receiving UA Formula Funds are not included (e.g., agencies exclusively providing paratransit services that do not receive UA funds). This means that national totals of fatalities, injuries, and incidents for transit are slightly understated in the NTD. The degree of understatement can be estimated from data published by the American Public Transit Association, which estimates that nationwide transit passenger-miles in 1995 were 39,815 million (APTA 1996), as compared with the 37,970 million reported in the NTD. Thus, in 1995, the NTD covered 95 percent of transit service nationwide as measured in passenger-miles. Since the numerators (i.e., adverse outcome counts) and the denominators (i.e., exposure measures) for rate variables are both slightly understated, it is likely that the rates are even less in error than the totals.

Recreational Boating

Recreational boating differs from most other modes in two ways: almost all usage of this mode is discretionary, and the purpose of trips is primarily to spend time on the water, not to get from one point to another. It shares these characteristics with recreational walking and bicycling, which, however, do not comprise all walking and bicycling trips. Recreational flying and touring on a motorcycle or in an automobile also share these characteristics, but very often combine recreational objectives with destination-oriented travel.

The recreational purpose of most boating makes it hard to quantify risk exposure. Miles of travel are hard to estimate. Many boats do not have equipment to record travel distance. Moreover, this measure is not very meaningful, since traveling to a predetermined destination is seldom the purpose of a recreational boating trip. The number of trips is also not a good exposure measure, as a trip of longer distance or duration involves greater exposure to risk than a short-distance, short-duration trip. The longer the trip, the more likely the boaters are to be exposed to hazards such as submerged rocks or bad weather. Duration of trips (in boat-hours) may be the best measure of exposure. It reflects exposure to common hazards (e.g., human errors, weather, and equipment failure) and also expresses activity time on the water. Trip duration data are hard to collect, however.

At present, the U.S. Coast Guard (USCG) uses the number of registered boats (11.9 million in 1996) as an exposure measure. All boats, however, are not registered and all registered boats may not be in active use. Moreover, among boats in active use, some are used very infrequently, some are used seasonally, and some are used throughout the year.

The counts of fatalities, injuries, accidents, and property damage, especially the last three, are subject to underreporting. For example, all boating accidents involving a fatality, an injury requiring treatment beyond first aid, a missing person, complete loss of the vessel, or damage to the vessel or other property of $500 or greater are required to be reported to the Coast Guard (33 CFR 173). The requirement is hard to enforce, and the number of reported accidents—about 8,000 in 1996—excludes the many unreported accidents. While the great majority of fatalities and missing persons are reported promptly, that is not necessarily the case with injuries, nonfatal accidents, and property damage.

Commercial Waterborne Transportation

Currently, the Coast Guard collects extensive data on incidents, fatalities, injuries, property damage, and pollution, but there are no equivalent exposure data. One of the major problems with selecting an appropriate exposure measure is that the nature of the risk is very different for a vessel on coastal waters, on the deep sea, or on inland waterways. In the vicinity of ports, traffic volumes are high, leading to the risk of collisions between vessels, especially in passing and overtaking situations. Also, in these waters, proximity to the land and land-based facilities greatly increases the risk of groundings and collisions with bridges.

For deep sea navigation, most of these hazards are negligible, or, in some cases such as collisions with bridges, nonexistent. Other kinds of hazards, such as vessels capsizing from waves and winds, or crew being swept overboard, are important for both deep sea and coastal navigation. Therefore, the risk profile for oceangoing vessels approaching ports is very different from their risk profile during most of their operation. That is why many vessels are required to use local pilots during the final approach from a sea buoy to a port.

For inland waterway navigation, however, the near-port hazards described above are present in all phases of operation. Because of shoaling, grounding is a major risk on inland waterways, especially the Mississippi River, and sharp turns and complex maneuvers are risky for large vessels and for tows with multiple barges.

Great Lakes shipping presents a range of exposure situations. A vessel sailing from a Lake Superior port to a Lake Michigan port encounters the equivalent of deep sea exposure in Lake Superior, Lake Huron, and Lake Michigan, and near-port type exposure in the passages between the lakes. Ice can also be a problem during the winter.

Several different safety rate data sets would be needed to characterize safety regimes as diverse as those described above. For example, further research would be needed to determine the feasibility of constructing vessel-miles data. The Census Bureau collects vessel movement data that includes port entrances and clearances, but is restricted to vessels engaged in foreign trade. It should in theory be possible to combine vessel inventory data with vessel logs to construct all required exposure data, but that would entail a costly data-collection program and a major analytical effort. A simpler approach might be to require installation of data recorders onboard oceangoing vessels. A further complication in evaluating exposure arises for commercial fishing, which is included in the safety statistics for waterborne transportation.

Hazardous Gas and Liquid Pipelines

Gas and hazardous liquid pipelines account for a large portion of the domestic movement of petroleum, natural gas, and similar products. Pipeline networks span 1.46 million miles in the United States. Currently, pipeline information in publicly available geographic databases is limited. The Office of Pipeline Safety (OPS) within DOT's Research and Special Programs Programs Administration collects data on incidents, fatalities, and injuries caused each year by pipeline activities. In addition, OPS serves as the lead federal agency on the joint Government-Industry Pipeline Mapping Team, aimed at developing and maintaining a national digital database on pipelines.

As noted in *Transportation Statistics Annual Report 1997*, there is a lack of good exposure data to gauge the risk of pipelines and their products. Specific exposure is an important determinant of risk. Excavation activities or pipeline ruptures around populated areas and buildings, such as the deadly explosion in San Juan mentioned earlier, are of particular concern to safety officials. Even in relatively unpopulated regions, pipelines present exposure risks, such as areas susceptible to seismic activity, mud slides, or flood washouts. The only national measure of exposure now available is miles of pipeline. Dividing fatalities by miles of pipeline, however, averages out all specific risk factors, which are important in pipeline safety analysis. It would be equivalent to dividing road fatalities by miles of trafficway, a decidedly crude measure of exposure.

Accident data needs to be collected and reported in sufficient detail to show the cause and related factors that would either decrease or increase the likelihood of occurrence (NTSB 1996). Because of regulatory arrangements, pipeline operators do not have to notify OPS of all pipeline hits during excavations, but only ones that meet certain criteria. Data on these unreported incidents could be extremely valuable as an aid in determining potential risk from particular types of exposure.[5]

CAUSES OF CRASHES AND ACCIDENTS

Good data can improve understanding of the causes of transportation crashes and accidents. This understanding, in turn can then lead to more focused prevention strategies and priority setting. Assigning causes for accidents is not an easy task; typically, transportation accidents are a complex sequence of events, with more than one cause. In addition, it is important to distinguish between causation and association. The presence of a condition at the time and place of an accident does not necessarily mean that the condition caused the accident. Finally, cause data must be mode-specific. Because the modes differ, causes of accidents and thus effective prevention strategies will differ.

In this section, the causes of transportation accidents are assigned to five broad categories, which are then used to discuss accident causation by mode. The categories are:

- *Human factors.* These include errors of judgment, violations of traffic laws, and errors in operation of vehicles or equipment. Errors by operators of traffic control equipment (e.g., air traffic controllers and railroad signal operators) are included.
- *Equipment failure.* These include failure of some part of the vehicle that leads to loss of control, fire or an explosion, overturning, or loss of power. Often, equipment failures can be traced back to a human error, such as in design, quality control, maintenance, repairs, and inspection. Because they do not involve a human error on the part of an operator or traffic controller, they are not counted in the human factors category.
- *Weather conditions.* The safety of all modes is affected by weather conditions. Atmospheric and water conditions can cause loss of control or overturning of a vehicle, or loss of visibility resulting in a crash. The conditions that pose the biggest risk vary by mode. Weather is analyzed separately here, rather than being grouped with factors in the physical environment listed under "other causes" below. Weather as a cause is of special interest because current technologies make it feasible to provide short-term, small-scale weather forecasts that can greatly enhance safety across modes through prevention methods. The potential to use this information in personal transportation vehicles, such as cars and boats, is growing (see box 3-3).
- *Infrastructure failure.* This category includes structural defects in trafficways (e.g., highways or railroad tracks), as well as in terminal facilities (e.g., runways and piers), that cause or influence accidents. Infrastructure failure as a cause is significant for certain modes (e.g., rail) and negligible for others (e.g., waterborne).
- *Other causes.* In addition, there are, for all modes, other causes that cannot be classified into the above four categories. These include, for instance, factors in the physical environment (other than weather) that affect trans-

[5] NTSB has expressed concern about the ability of OPS to collect and analyze accident data for petroleum pipelines, to identify accident trends, and to evaluate operator performance (NTSB 1996).

Box 3-3.
Highway Safety Applications of Advanced Weather Information Technologies

Weather information techniques and technologies are advancing quickly, and include observation technologies such as NEXRAD doppler radar, the Geostationary Operational Environmental Satellite (GOES), Automated Surface Observation Systems (ASOS), and the Advanced Weather Interactive Processing System (AWIPS). These technologies have greatly improved the spatial and temporal resolution of weather forecasts. Numerical forecast models have also become more powerful and accurate.

Road Weather Information Systems (RWIS) are decisionmaking methodologies incorporating weather data, which are used by several state transportation departments in coordination with local governments, to deploy winter maintenance equipment and emergency response crews to the right place at the right time. RWIS are useful for fast, effective response to winter storms and other weather events that threaten highway safety.

The federally funded Advanced Transportation Weather Information System project in North and South Dakota is fully operational. The project entails collection of weather data through road and weather sensors, GOES observations, and an agricultural surface weather mesonet. The data are converted into site-specific nowcasts[1] and forecasts, which are made available to highway maintenance departments in both states through electronic mail, and to motorists through cellular phone. The Nevada Department of Transportation uses data collected for RWIS to provide advisories to motorists through variable message signs, weather advisory radio, and a local television station.

Technologies still under development could allow the dissemination of up-to-date weather information to operators of surface transportation vehicles in a form suitable for decisionmaking. A new initiative called Foretell aims to develop a nationwide system of roadway weather services that will benefit travelers on and maintenance of highway systems. Foretell is a joint partnership of the Federal Highway Administration, contractors, state departments of transportation, and the National Center for Atmospheric Research.

The increased use of weather information to enhance transportation safety is not merely a question of making weather data available. Decisionmaking methodologies have to be developed with the weather data serving as inputs. Particularly for the highway mode, most final users of the data will be the general public, without training in interpretation of weather data. The data must be accompanied by instructions on route selection, safe speeds, and other driving tips to minimize risk. Research is also required in human factors technology, so that the weather warnings are displayed in a user-friendly format.

[1] A nowcast is a very short-term forecast of current weather conditions with a high spatial resolution.

portation safety. Examples include: earthquakes for pipelines and transportation infrastructure; natural light conditions, icebergs, and submerged rocks for the waterborne mode; rockslides for highways and railroads; and obstructions for airplanes, including buildings, power lines, towers, mountains, and other hazardous objects above the surface.

Detailed data on causation are not available for all modes. This section analyzes existing data that are related to causation, and explains data limitations and gaps. Transit is not discussed because of lack of data; the profile of accident causation for transit, however, is likely to be a combination of the profiles for highway and rail, because most transit submodes operate either on roads (buses, vanpools, demand response) or on rails (light rail, heavy rail, commuter rail).

Highway

The highway mode accounts for the vast majority of transportation fatalities and injuries (see table 3-1). Highway crashes are frequent and widely dispersed geographically, with each crash usually accounting for only a few fatalities and injuries. Cause assignment can be difficult to determine.

Some causation data are collected and reported on a national level about fatal crashes, mainly a list of human factors pertaining to drivers, and similar data for pedestrians and pedalcyclists. Table 3-5 identifies factors for drivers in fatal crashes based on a sample of motor vehicle crash data. Note that the total of the percentages for all factors is greater than 100, because multiple factors can be assigned to the same driver. Categories 7 and 11 in the table include environmental factors, especially weather. Category 13, "other factors," consists exclusively of human factors, as do all categories other than 7, 11, 14, and 15. For categories 14 and 15, no factors were assigned, or the factors could not be determined. Thus, the degree of involvement of human factors can be estimated by subtracting out categories 7, 11, 14, and 15. This is an underestimate, as human factors may have played a role in some of the excluded categories (e.g., the 36 percent that were not assigned a cause), but it is nevertheless an instructive way to estimate the importance of human factors in fatal crashes.

Even with the exclusions listed above, table 3-5 shows that human error was a factor for at least 56 percent of drivers involved in fatal crashes in 1995. Other causative factors are harder to quantify for the highway mode. Relevant data are either not collected, or are collected in insufficient detail for

Table 3-5.
Contributing Factors Attributed to Drivers in Fatal Crashes: 1995

Category	Factor	Number of drivers[1]	Percent[1]
1	Failure to keep in proper lane or running off road	15,873	28.3
2	Driving too fast for conditions or in excess of posted speed limit	11,656	20.8
3	Failure to yield right-of-way	4,868	8.7
4	Inattentive (talking, eating, etc.)	3,323	5.9
5	Failure to obey traffic signs, signals, or officer	3,189	5.7
6	Operating vehicle in erratic, careless, reckless, or negligent manner	2,850	5.1
7	Swerving/avoiding due to wind, slippery surface, vehicle, object, nonmotorist in roadway, etc.	1,926	3.4
8	Drowsy, asleep, fatigued, ill, or blackout	1,816	3.2
9	Driving wrong way on one-way trafficway or on wrong side of the road	1,387	2.5
10	Overcorrecting/oversteering	1,328	2.4
11	Vision obscured (rain, snow, glare, lights, building, trees, etc.)	1,309	2.3
12	Making improper turn	1,253	2.2
13	Other factors	9,096	16.2
14	None reported	20,443	36.4
15	Unknown	990	1.8
	Total drivers	56,155	

[1] The sum of numbers and percentages exceeds the total number of drivers in fatal crashes (56,155 in 1995) because more than one factor may be present for the same driver.

SOURCE: Based on a sample of data from U.S. Department of Transportation, National Highway Traffic Safety Administration, Fatality Analysis Reporting System (FARS, formerly called the Fatal Accident Reporting System) in *Traffic Safety Facts 1995* (Washington, DC: 1996), table 61.

assigning causes or for making correlations. For instance, FARS and the General Estimates System (GES) (see box 3-2) do not include the condition of the infrastructure. (There is a data element on surface condition, but this refers to weather-related conditions such as dry or wet pavement or presence of ice or snow.) FHWA collects data on the surface condition of a sample of roadways (USDOT FHWA annual issues, table HM-63), but there are no corresponding data on crash occurrence by roadway condition, or on exposure (i.e., vehicle-miles traveled) by roadway condition.

FARS and GES include data on atmospheric conditions, as well as surface conditions. In 1995, 86 percent of fatal crashes occurred in normal weather, and 14 percent in bad weather. Because a crash occurs in bad weather does not necessarily mean that the weather caused the crash. Current data are insufficient to determine the *exposure* of highway drivers and passengers to the risk of death or injury in bad weather. Even where the necessary data are available, analyses tend to have little applicability beyond the specific locality and cannot be applied at a national level.[6] For example, to estimate the impact of wet pavement on crashes, it is essential to know the fraction of time for which the pavement is wet, how much driving occurs on wet pavement, and how many crashes occur on wet pavement.

In conclusion, quantitative information about the effect of weather on highway safety is limited; this is an area where extensive research is needed. For example, fog and ice have not received much attention; most of the research has focused on rain. Even for rain, the studies have not yielded a consistent, accurate methodology for integrating crash data and weather data locally and nationally to determine the added risk because of rain-induced loss of visibility and wet pavement.

[6] One study (Jones et al 1991) examined the correlation between crash frequency and several conditions, including wet pavement and rain, for six highway zones around Seattle, Washington. It found wet pavement had a significant positive correlation with crash frequency in these highway zones, while rain had a significant positive correlation with crash frequency in two of the six zones in which driving requires complex maneuvers. While useful for assessing weather effects on highway safety, this study is too location-specific to identify overall effects of rain or wet pavement on crash rates for U.S. highways.

Aviation

The National Transportation Safety Board publishes detailed accident causation statistics for the four air submodes (i.e., part 121, major carriers; commuter airlines; air taxi; and general aviation) in the *Annual Review of Aircraft Accident Data* (NTSB annual a and b), with multiple causes assigned to each accident. Table 3-6 shows the 10-year average distribution of causes for all the air submodes. Fatal accidents for all submodes except general aviation, and all accidents for major carriers and commuter air, are relatively few in number each year. Even among all accidents for air taxi, there is a considerable degree of volatility in the annual data, a direct statistical result of the small number of accidents. For this reason, trends in the above are not discussed; analysis is confined to the 10-year averages shown in table 3-6.

Besides the "other" category, there are only three cause categories for aviation accidents: human factors, weather, and equipment failure. As shown in the table, human factors contribute to 90 to 100 percent of air accidents, including errors made by pilots, other people aboard (e.g., flight instructors), and air traffic controllers.

The air mode is affected by both surface weather and weather at higher altitudes. It is also affected by very sudden, short-duration weather phenomena such as microbursts and turbulence. Examples of phenomena that affect the air mode are atmospheric turbulence, convection wind shear, and wake vortex (the disturbance associated with the passage of another aircraft). In

Table 3-6.
Causes/Factors for Aviation Accidents
(Average: 1985–94)

Causes/ factors	Major carriers, fatal	Major carriers, all	Commuter air, fatal	Commuter air, all	Air taxi, fatal	Air taxi, all	General aviation
Total aircraft	47	256	52	195	274	1,009	23,103
Human factors[1]	42	230	65	221	294	941	20,991
	89%	90%	100%	100%	100%	93%	91%
Equipment failure[2]	18	97	20	78	93	420	7,760
	38%	38%	39%	40%	34%	42%	34%
Weather	9	76	22	60	121	320	5,243
	19%	30%	42%	31%	44%	32%	23%
Other[3]	10	48	25	97	173	570	10,470
	21%	19%	48%	50%	63%	57%	45%

[1] Sum of the categories "Pilot," "Other Person (Not Aboard)," and "Other Person (Aboard)" for 1987–94. Sum of the categories "Pilot" and "Personnel" for 1985 and 1986.
[2] Sum of the categories "Propulsion System and Controls," "Landing Gear," "Systems/Equipment/Instruments," "Airframe," and "Flight Control Systems" for 1987–94. Sum of the categories "Powerplant," "Landing Gear," "Airframe," "Systems," "Rotorcraft," and "Instruments/Equipment/Accessories" for 1985 and 1986.
[3] Sum of "Terrain/Runway Condition," "Object (tree, wires etc.)," "Light Conditions," and "Airport/Airways Facilities, Aids" for 1987–94. Sum of "Terrain," "Miscellaneous," "Undetermined," and "Airport/Airways/Facilities" for 1985 and 1986.

NOTE: Percentages add up to greater than 100% because multiple causes/factors may be assigned to each accident.

SOURCES: All data are from the series of reports by the National Transportation Safety Board, under the general title of *Annual Review of Aircraft Accident Data.* Specifically, data for each category above are from:
Air carrier data: *U.S. Air Carrier Operations*, 1986–94, table 19; tables 23 and 24.
Commuter air: *U.S. Air Carrier Operations*, 1989–94, table 37; 1986–88, table 38; 1985, tables 48 and 49.
Air taxi: *U.S. Air Carrier Operations*, 1989–94, table 55; 1986–88, table 56; 1985, table 65.
General aviation: *U.S. General Aviation*, 1989–94, table 55; 1986–88, table 56; 1985, table 26.

addition, the precipitation, storms, ice, and fog that affect all modes can affect aviation in unique ways. For example, while the effect of ice on runways is analogous to the effect of ice on highways, icing of the airframe of an aircraft causes increased drag. A special case of icing is the occurrence of supercooled drizzle drops (SCDDs), which freeze on impact with the airframe. SCDDs are thought to be a factor in the October 1994 crash of a commuter aircraft near Roselawn, Indiana, which resulted in the deaths of all 68 people aboard.

The importance of the "other" category (e.g., environmental hazards such as terrain, buildings, trees, wires, and natural light conditions) is significantly different between major carriers and all other submodes, particularly general aviation. Major carriers use large, technologically sophisticated aircraft that are less dependent on pilot vision. Hence, if all equipment is working properly, light conditions are relatively unimportant. Also, large aircraft land at big airports, where there are likely to be fewer hazards such as trees and wires.

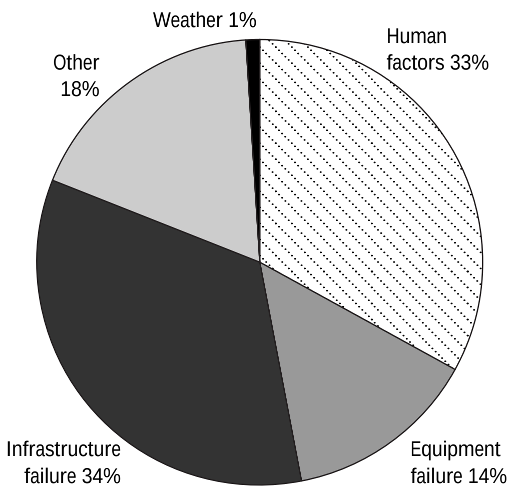
Rail

The Federal Railroad Administration publishes detailed accident causation data, which is grouped into human factors, equipment failure, infrastructure failure, weather, and other causes (see figure 3-4). Several features are noteworthy.

Infrastructure failure as an accident cause is more important for rail (averaging 34 percent

Figure 3-4.
Single Causes Ascribed to Railroad Accidents: 1986–95

(10-year average)



SOURCE: U.S. Department of Transportation, Federal Railroad Administration, *Accident/Incident Bulletin* (Washington, DC: Annual).

between 1986 and 1995) than for other modes examined. Because rail operates on a fixed guideway, the condition of the infrastructure is critical. Typical infrastructure defects include settled or soft roadbeds, track geometry defects, rail and joint bar defects, and signal failures.

Human error by train operators and traffic controllers is responsible for about one-third of rail accidents—a smaller fraction than for other modes because of the fixed guideway operation.

Equipment failure declined as a cause of accidents, from nearly 16 percent in 1986 to nearly 11 percent in 1995. There is also a distinct decline in the absolute number of accidents caused by equipment failure over this period, some of which may be attributed to the retirement of old rolling stock (locomotives and freight cars) and their replacement by rebuilt or new rolling stock. Data published by the Association of American Railroads show that the percentage of new and rebuilt freight cars in the fleet increased from a low of 0.9 percent in 1986 to a high of 5.4 percent in 1995, and the percentage of new and rebuilt locomotives in the fleet increased from 2 percent in 1986 to 6 percent in 1995 (AAR 1997). (Overall, the freight car and locomotive fleets decreased during this period.)

Weather contributed to only 1 to 2 percent of all rail accidents over the period. Once again, the fixed guideway operation of the rail mode is a factor. Because of signaling and switching procedures, visual judgment is relied on less when there is fog or precipitation. Major weather-related safety concerns focus on how the tracks are affected—washout by flash floods and mudslides, warping from thermal expansion, brittleness from extreme cold, and derailment because of snow or ice.

WATERBORNE TRANSPORTATION

Waterborne transportation, both commercial shipping and recreational boating, faces exposure to environmental hazards not present for other modes. These hazards can be important factors causing or contributing to accidents, and may be navigational, such as silting, shoaling, and debris, or weather-related. In the case of weather-related hazards, the risk of persons being swept overboard by wind and waves, or falling overboard due to the rolling and pitching motion in rough waters, has no counterpart in other modes. Two other weather-related hazards are the risk of vessels sinking because of excessive water intake through the hull (associated with rough waters), and the risk of capsizing in strong winds or roughs waters. These phenomena affect recreational boats, in particular, because of their small size.

Commercial Waterborne Transportation

The U.S. Coast Guard investigates waterborne accidents and assigns four categories of causes: human factors, equipment failure, weather, and hazardous materials. The information collected is entered into the Marine Safety Management Information System (MSMS database) (USDOT USCG 1997).

USCG often assigns multiple causes to a single accident. The categories of causes examined here are: human factors, equipment failure, weather, and other.[7]

Figure 3-5 shows that, as with all modes except rail, human factors are the dominant cause of accidents (75 percent). Examples of human error include misinterpreting or ignoring hazard warnings, operating in adverse conditions without adequate monitoring, and navigational errors. Equipment failure is the next largest category (16 percent). Typical cases of equipment failure include malfunctioning deck machinery, steering system, propulsion system, electrical system, and fuel system.

Weather accounts for 7 percent of accident causes. A hazard for operations in confined waterways, particularly with high vessel traffic, is the risk of collision between vessels, or between a vessel and a facility such as a pier or bridge, in conditions of poor visibility caused by fog or precipitation. This is especially a factor for inland waterways such as the Mississippi River, and in and around ports. (Weather-related causes are discussed in greater detail under recreational boating.)

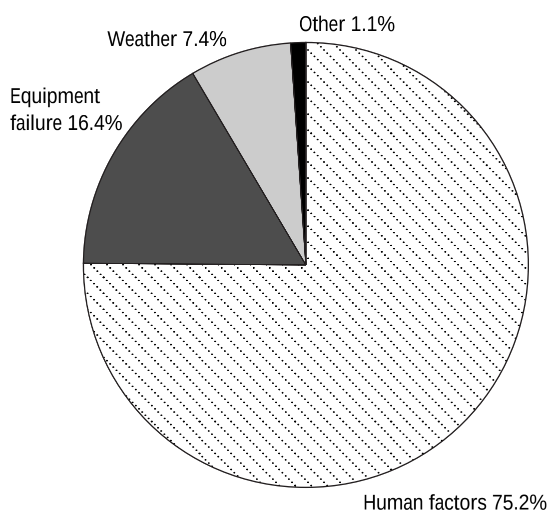
[7] The first two categories correspond to those in the MSMS data. For the last two categories, the data have been combined to make them more comparable to the discussion of the other modes. For weather, in addition to the condition of the air and water (e.g., storms, fog, waves, and currents), the MSMS database includes navigational hazards such as silting, shoaling, and debris. These navigational hazards are combined with the MSMS hazardous materials category and are shown as "other" in figure 3-5.

Recreational Boating

USCG publishes accident causation data for recreational boating in its annual publication, *Boating Statistics* (USDOT USCG annual). These data are shown in figure 3-6, covering the period 1985 through 1994. The data are based on single-cause assignments, as for rail.

As with most other modes, human factors are the dominant cause of recreational boating accidents, as was the case for three out of five boats involved in accidents between 1985 and 1994. (Note that the recreational boating data are for number of vessels rather than for number of accidents. Thus, if one vessel failed to yield the right-of-way because of improper lookout, and rammed another vessel, the accident would appear as two boats involved in accidents caused by human factors: one case of improper lookout, and one case of other vessel being at fault.

Figure 3-5.
Causes Ascribed to Commercial Marine Transportation Accidents: 1990–June 1996

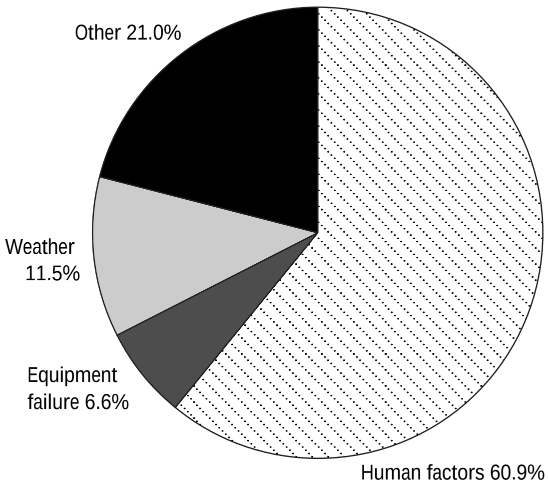


NOTES: Only accidents involving a fatality, a missing person, or an injury, o at least $25,000 in damages are included. More than one cause may be ascribed to an accident.

SOURCE: U.S. Department of Transportation, U.S. Coast Guard, Marine Safety Information Management System (MSMS) database.

Figure 3-6.
Causes Ascribed to Recreational Boating Accidents: 1985–94

(10-year average)



SOURCE: U.S. Department of Transportation, U.S. Coast Guard, *Boating Statistics* (Washington, DC: Annual issues).

In recreational boating, there are two broad classes of human factors: incorrect loading of passengers and gear, including overloading, improper weight distribution, and leaning over the edge of the boat; and incorrect operation of vessel, including improper lookout, inattention and carelessness, errors by other vessels, high-speed maneuvers, and navigational errors. Human factors are relatively less important for recreational boating than for commercial shipping, because weather and miscellaneous causes are relatively more important.

Weather was cited as a cause for about one out of every eight recreational boats involved in accidents. The percentage is slightly higher than the corresponding percentage for commercial waterborne transportation, because recreational boats are smaller and more vulnerable to wind and waves. The weather category includes strong currents and rough waters, wake or wave striking vessel, free water in boat, and poor visibility.

Equipment failure caused less than 7 percent of recreational boating accidents in this period. Equipment failure is relatively less important for recreational boating than for commercial waterborne transportation, because of the greater importance of weather and miscellaneous causes.

Other causes not classifiable into any of the previous three categories are collectively the second largest accident cause category for recreational vessels, an average of 21 percent between 1985 and 1994. Most of these are submerged objects, or classified as other and unknown in the *Boating Statistics* data.

Pipelines

DOT's Office of Pipeline Safety collects data on the causes of hazardous liquid pipeline and gas gathering and transmission pipeline accidents. These data are not published, nor are they sufficiently detailed for the kind of analysis done for the air, rail, waterborne, and recreational boating modes.

The cause categories used by OPS for hazardous liquid pipelines are: 1) corrosion, 2) equipment malfunction, 3) failed pipe, 4) failed weld, 5) incorrect operation, 6) outside force damage, and 7) other. For the 1986 to 1996 period, the first four categories (all involving equipment failure), accounted for 41 percent of incidents. (Note that for pipelines, the distinction between infrastructure and equipment is hard to draw; all of these causes may also be treated as infrastructure failure.) Incorrect operation accounted for slightly more than 6 percent of the incidents. This percentage only accounts for a portion of human factors as a cause of pipeline incidents, however. The "other" category also includes cases of human error, such as damage caused by pipeline construction and maintenance activities including replacement of pipeline sections and recoating (USDOT RSPA OPS 1998).

While human factors are clearly a large part of the outside force damage category, the unpublished OPS data do not distinguish between different types of this damage. An NTSB analysis of causation data for hazardous liquid pipelines found that 85 percent of outside force damage was caused by excavation by the pipeline company or its contractors, or by third parties such as utility companies, clearly cases of human error (NTSB 1996). Another 8 percent is attributable to fishing, ship anchors, and other marine activity (all human factors-related) and landslides, earthquakes, or washouts (all environmental factor-related). The remaining 7 percent of outside force damage cases are classified by NTSB as “other and unknown” (USDOT RSPA OPS 1998).

The cause categories used by OPS for gas pipelines are: 1) corrosion, 2) construction/material failure, 3) outside force damage, and 4) other. The first two can be classified as equipment failure, and together averaged about 36 percent of incidents between 1986 and 1996 (USDOT RSPA OPS 1998). As for the last two categories, it is not possible to determine the magnitude of human factors and environmental conditions from the data. As with hazardous liquid pipelines, the high proportion of accidents caused by outside force damage underscores the need for developing detailed, accurate local maps of pipeline location to prevent excavation and marine activity accidents.

TRANSPORTATION SAFETY AND THE ELDERLY

The number of older people in the United States is growing, in absolute numbers and as a percentage of the population, as it is in other industrialized countries. As of 1996, there were approximately 24 million people aged 70 or over. Their share of the population has been rising for over 10 years, and the U.S. Census Bureau projects that the fraction of the population over 75 years of age will increase from 12.1 percent in 2000 to 18.5 percent in 2025. It will be a rapidly expanding age group, rising over 78 percent during the period, compared with an increase of 22 percent for the population as a whole (USDOC 1997, 25).

The average level of health, and the associated motor skills and perceptual skills such as vision and hearing, of older people (e.g., 65 to 74 years old) is better today than it was in 1970, and is expected to continue improving with advances in health care.

From 1985 to 1995, the number of licensed drivers over the age of 70 grew 48 percent, compared with a 13 percent increase in the total population of licensed drivers. There are now almost 17 million drivers who are 70 years or over (USDOT NHTSA 1997). Older motor vehicle operators will become increasingly common in the future given demographic trends. Many older people also work part time or do volunteer activities that require them to drive. Because of these trends, a growing number of older people will be exposed to transportation risks as operators, passengers, and bystanders.

A recent study found that the mobility requirements of older people diminish only slightly once they have left the civilian labor force (Coughlin and Lacombe 1997). For most, the daily exigencies of life are such that they still need transportation to achieve their goals. The dispersion of housing, shopping, and services that has accompanied widespread suburbanization during the past few decades has lessened the effectiveness of most traditional mass transit solutions. Hence, the elderly must continue to provide for their own mobility; those who do not want to drive, or who cannot drive, are dependent on family members or their communities for transportation.

While some elderly drivers may have shortfalls in physical and cognitive abilities, and reduced abilities to survive injuries like those incurred in transportation crashes, age and experience also can have beneficial effects on vehicle operator performance. Elderly drivers are less likely to drive under the influence of alcohol; in 1996, of all drivers in fatal crashes in the United States, 19 percent were intoxicated, while of drivers 70 years and older in fatal crashes, only 4 percent were intoxicated (USDOT NHTSA 1997). Similarly, younger drivers are more likely to speed than older drivers. Studies in California have shown that the rate of speeding violations per mile traveled is at least three times as high for drivers in the 16 to 19 age group as it is for drivers over 30 years of age. Furthermore, NHTSA analysis found that the proportion of speed-related fatal crashes decreases with increasing driver age, from 37 percent for drivers aged 14 to 19, to 7 percent for drivers aged 70 and above (IIHS 1998). Other potential beneficial effects of age and experience on driving are harder to quantify. These include the possibility that older people drive less aggressively and with greater caution, and drive less in riskier situations, such as at night and in poor weather.

With improvements in health and healthcare, it is possible that the number of older commercial vehicle operators will increase, to the extent that retirement age is at the discretion of the operator. The *Code of Federal Regulations* (49 CFR 391, Subpart E) specifies health requirements for commercial motor vehicle operators, but no age requirement other than that they be above 21 years of age. Under Federal Aviation Administration regulations, pilots of certificated air carriers must be under 60 years of age. There is no age limit for other commercial pilots or for general aviation pilots. Individual trucking companies, school districts, transit agencies, railroads, and other employers, however, have their own policies on retirement age for those who drive as part of their profession.

Private Motor Vehicle Operators

Based on estimated miles driven by age group, the fatality rate for drivers aged 65 and older is 17 times as high as for drivers aged 25 to 65 (USDOT NHTSA 1997). The reasons for this dramatic difference are unclear. It may reflect the small sample size (by age group) of the survey used to estimate mileage, rather than real conditions. It is plausible, however, that fragility may be a factor. Older motor vehicle drivers and occupants are more likely to be killed in crashes in which younger, more physically robust people may suffer injuries that are nonfatal. Greater incidence of posttraumatic cardiac risk is one example of increased fragility with age (DeMaria 1993).

Motor vehicle crash profiles for aging drivers are somewhat different from those of other age groups: there are more crashes involving left turns, intersections crashes, and crashes where no evasive actions were taken. Research is underway on techniques such as larger, brighter, and more legible signs and widely spaced, raised pavement markers, which might be helpful for older drivers (TranSafety 1997).

There are some safeguards built into the driver license renewal system, which protect against the possibility of physically impaired drivers, *elderly or otherwise*, renewing their licenses and thereby endangering themselves as well as other highway users (USDOT FHWA 1996, US-8). Of the 50 states, the District of Columbia, and Puerto Rico, only 12 did not require a vision test for drivers renewing their licenses in 1995. Some states require reexamination of general driving knowledge and knowledge of signs and signals, and at least one state (Utah) also requires reexamination of vehicle operation skills for renewal, subject to discretionary waivers. In addition, some states require medical examinations of renewal applicants above a certain age; this age varies depending on the state. In some states, medical examinations are at the discretion of the examiner.

Older Pedestrians

Persons aged 70 and above (about 9 percent of the total population) represented 17 percent of all pedestrian fatalities in 1996. This group had a pedestrian fatality rate per capita about twice that of the entire population (39 fatalities per million persons, as compared with an overall rate of 20 fatalities per million persons, in 1996). It is unclear whether the higher fatality rate of older pedestrians reflects increased exposure due to more time spent walking, a slower pace and decreased attentiveness when crossing streets, or frailty when injured.

REFERENCES

American Public Transit Association (APTA). 1996. *Transit Fact Book: 1995 Edition*. Washington, DC.

Association of American Railroads (AAR). 1997. *Railroad Facts: 1996 Edition*. Washington, DC.

Blincoe, L.J. 1996. *The Economic Cost of Motor Vehicle Crashes*. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration.

Coughlin, J.F. and A. Lacombe. 1997. Ten Myths About Transportation for the Elderly. *Transportation Quarterly* 51, no. 1:91–100.

DeMaria, E.J. 1993. Evaluation and Treatment of the Elderly Trauma Victim. *Clinics in Geriatric Medicine* 9, no. 2:461–471.

Farmer, C.M., R.A. Retting, and A.K. Lund. 1997. *Effect of 1996 Speed Limit Changes on Motor Vehicle Occupant Fatalities*. Arlington, VA: Insurance Institute for Highway Safety. November.

Insurance Institute for Highway Safety (IIHS). 1998. *Q&A: Speed Limits*. Available at http://www.hwysafety.org/.

Jones, B., L. Janssen, and F. Mannering. 1991. Analysis of the Frequency and Duration of Freeway Accidents in Seattle. *Accident Analysis and Prevention* 23, no. 4:239–255.

National Civil Aviation Review Commission (NCARC). 1997. *A Consensus for Change: Avoiding Aviation Gridlock and Reducing the Accident Rate*. Washington, DC.

National Transportation Safety Board (NTSB). 1996. *Pipeline Special Investigation Report: Evaluation of Accident Data and Federal Oversight of Petroleum Product Pipelines*, NTSB/SIR-96/02. Washington, DC.

_____. 1997. San Juan Gas Company's Inadequate Training of Employee's and Government Deficiencies Led to Building Explosion, NTSB Says. Press release. 16 December.

_____. 1998a. Abstract of Final Accident Report: Bi-State Development Agency Transit Bus Collision with Pedestrians, Normandy, MI. 11 June 1997. Available at http://www.ntsb.gov/pressrel/.

_____. 1998b. New Orleans Freighter Accident Caused by Mechanical and Company Failures, NTSB Says. Press release. 13 January.

_____. Annual a. *Annual Review of Aircraft Accident Data: U.S. Air Carriers*. Washington, DC.

_____. Annual b. *Annual Review of Aircraft Accident Data: U.S. General Aviation*. Washington, DC.

TranSafety, Inc. 1997. Improving Highways for Older Driver Use. *Auto and Road User Journal*. 1 February. Available at http://www.usroads.com/journals/aruj. Cited as of 9 July 1998.

U.S. Department of Commerce (USDOC), Bureau of the Census. 1997. *Statistical Abstract of the United States.* Washington, DC.

U.S. Department of Health and Human Services (USDHHS), National Center for Health Statistics. 1997. *Health, United States 1996–97 and Injury Chartbook*. Hyattsville, MD.

U.S. Department of Labor (USDOL), Occupational Safety and Health Administration (OSHA). 1997. *Census of Fatal Occupational Injuries.* Washington, DC.

U.S. Department of Transportation (USDOT). 1997. Strategic Plan 1997–2002. 30 September.

U.S. Department of Transportation (USDOT), Bureau of Transportation Statistics (BTS). 1998. National Transportation Statistics 1998. Available at http://www.bts.gov/ntda/nts.

U.S Department of Transportation (USDOT), Federal Highway Administration (FHWA). 1996. *Drivers License Administration Requirements and Fees*. Washington, DC.

_____. Annual issues. *Highway Statistics*. Washington, DC.

U.S. Department of Transportation (USDOT), Federal Railroad Administration (FRA). 1997. Highway-Rail Crossing Accident/Incident and Inventory Bulletin: Calender Year 1996, No. 19.

U.S Department of Transportation (USDOT), Federal Transit Administration (FTA). Annual issues. *Safety Management Information Statistics (SAMIS) Report*. Washington, DC.

U.S. Department of Transportation (USDOT), National Highway Traffic Safety Administration (NHTSA). 1997. *Traffic Safety Facts 1996: Older Population*. Washington, DC.

_____. 1998. *Motor Vehicle Traffic Crashes as a Leading Cause of Death in the U.S., 1994,* Technical Report DOT H5 808 687. Washington, DC.

U.S. Department of Transportation (USDOT), National Highway Traffic Safety Administration (NHTSA) and Federal Highway Administration (FHWA). 1998. *Report to Congress: The Effect of Increased Speed Limits in the Post-NMSL Era,* DOT HS 808637. Washington, DC.

U.S. Department of Transportation (USDOT), Research and Special Programs Administration (RSPA), Office of Pipeline Safety (OPS). 1998. Personal communication.

U.S Department of Transportation (USDOT), U.S. Coast Guard (USCG). 1997. Marine Safety Management Information System (MSMS) database.

_____. Annual issues. *Boating Statistics*. Washington, DC.

U.S. Executive Office of the President (USEOP), White House Commission on Aviation Safety and Security. 1997. *Final Report to President Clinton*. Washington, DC.